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Figure 1. Air Force operators view missile warning data screens. The National Missile Defense system will rely on similar technology to assist operators in controlling a missile defense system.

Advocating User-Centered Software Design

Stephen Armstrong and
Richard Steinberg

Dr. Eli Goldratt, an Israeli physicist, once remarked, "Tell me how you will measure my work, and I'll tell you exactly how I will perform." In other words, expectations drive outcome, but in the Defense procurement process, product development can be guided by the wrong expectations or requirements. Particularly in the procurement of software systems, expectations for usability are often neglected, resulting in products with unnecessarily complex and awkward user interface designs that fall far short of commercial usability standards. Fortunately, human factors professionals participating in the software procurement process are helping to correct this problem.

First, consider an analogy: home construction. Building a custom home requires an architect, a contractor, an engineer, a mortgage lender, and a home buyer. Each participant holds different expectations for the final product. The contractor desires a home that is easy to construct; the architect desires a homes that is aesthetically pleasing; the engineer desires a home that is structurally sound; the lender desires a home that is worth its loan value; and the buyer desires all that and more—for a reasonable price. Bringing together these competing expectations yields a system of checks and balances, which offers the potential to produce the best possible home.

The same system of checks and balances should exist during the development of software systems. Programmers, designers, test engineers, project managers, and users naturally possess differing expectations for the final product. While engineers may seek reliability, efficiency, or interoperability, operators

continued on next page

in this issue:

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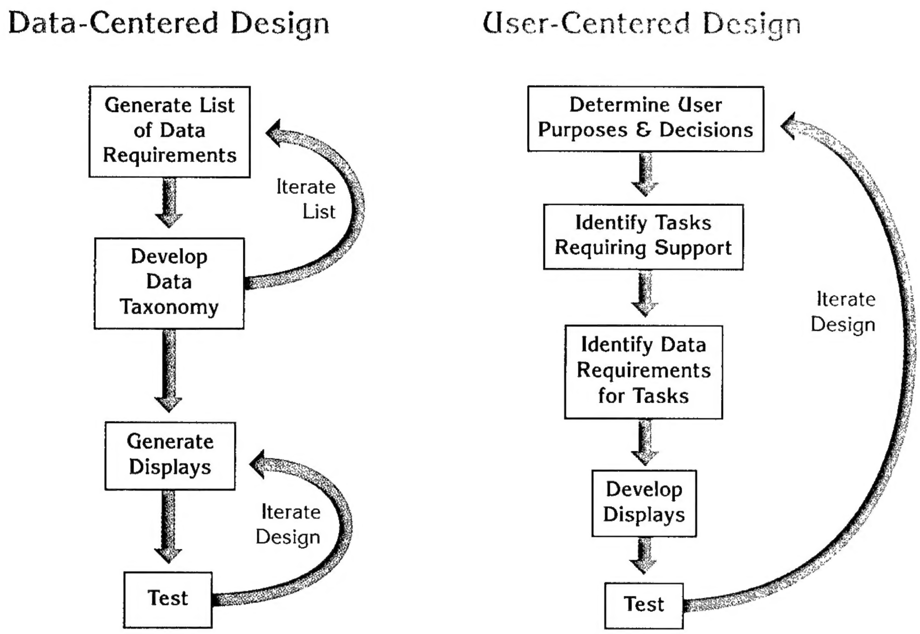


Figure 2. A General Overview of the Data-Centered User Interface Design Approach Compared to User-Centered Design Approach

generally seek usability and suitability to the task. Unlike custom home construction, however, the user is rarely involved directly in the development effort. Consequently, the user's interests must be represented by an advocate, an individual or group assigned to advance the cause of usability. The user advocate acts as a counterweight, ensuring that usability is not unfairly targeted when decisions to reduce cost, shorten schedule, or minimize risk are necessary.

Origins of Data-Centered Design

In the commercial world, user advocates have become commonplace. Human factors and other usability professionals routinely participate in the software development process as the user's voice. Armed with data from focus groups, usability studies, and other sources, these professionals help guide the development of sensible, user-friendly designs. Commercial developers have come to appreciate the importance of a user-focused effort, because they see its effect on their bottom line. Simply put, usable products sell better than unusable products.

Unfortunately, in most government software procurements the users are not the paying customers. The customer is usually a program office or product manager, whose expectations for product performance are stipulated in a system requirement document (SRD). Generally speaking, the SRD expresses the purchaser's (i.e., government's) expectations for product performance viewed from a systems engineering perspective.

Since the SRD is developed by individuals who are not the end users, most SRDs tend to emphasize data and functionality requirements, and to overlook usability concerns. Naturally, software developers must develop products that satisfy these engineering requirements. So based upon the SRD and other guidance, the developer submits a blueprint for the software in a software requirements specification (SRS), which usually echoes the SRD's emphasis on data and functionality. Consequently, unless usability is featured prominently in the SRD, it receives little attention in the final design, because the product "sells" even when the user interface is poor.

As Dr. Goldratt's comment suggests, emphasizing data and functionality in the requirements encourages the developer to follow a data-centered design process. Data-centered designs (usually constructed using traditional waterfall methods of software development) often force the operator to process and manipulate screens of raw data rather than offer ready-made tools designed to complement operator purposes.

If the dashboard of an automobile were designed according to a data-centered approach, the operator might see displays of technical data describing the status and performance of every subsystem in the vehicle. These tables and graphs of data would update continuously to reflect the ever-changing condition of each system. To control the vehicle, the operator would scan the displays for relevant information, process the data mentally to appreciate its meaning, determine the appropriate adjustment for a given value, and manipulate the value to effect the desired change. For example, the operator might be required to enter specific engine RPM values to control vehicle speed, input compass headings to control direction, or adjust the coolant flow rate to moderate engine temperature.

Of course, today's automobile driver would never tolerate this user interface, and any vehicle incorporating such a design would never sell. Drivers have come to expect displays that transform raw data into meaningful information and offer opportunities for control that reflect appropriate operator functions and tasks. Consequently, steering wheels, speedometers, and pedal accelerators are universal in automobiles, because these controls are better suited to controlling vehicle direction and speed. Likewise, an automatic thermostat is recognized as the appropriate way to control engine temperature.

The User-Centered Approach

Assuming the present procurement process is unlikely to change, how can the developer ensure a usable product while still satisfying the engineering design requirements? The answer may be found in adopting a user-centered rather than a data-centered design approach during the development effort. With a user-centered approach, developers can advance the cause of software usability even as they satisfy the requirements of the SRD. Essentially, user-centered design considers both operator performance and acceptance as well as product compliance with engineering requirements as criteria for suitability.

The process of user-centered or task-centered software design is well documented in industry literature (Lewis & Rieman [1993], Mandel [1997], among others) and in military publications, including Department of Defense Handbook #46855, which stresses the importance of a task-centered approach in the development of military systems, including software. Furthermore, a glance at the software development section of any bookstore quickly reveals the broad support user-centered design enjoys. An in-depth description of the user-centered design approach is beyond the scope of this article.

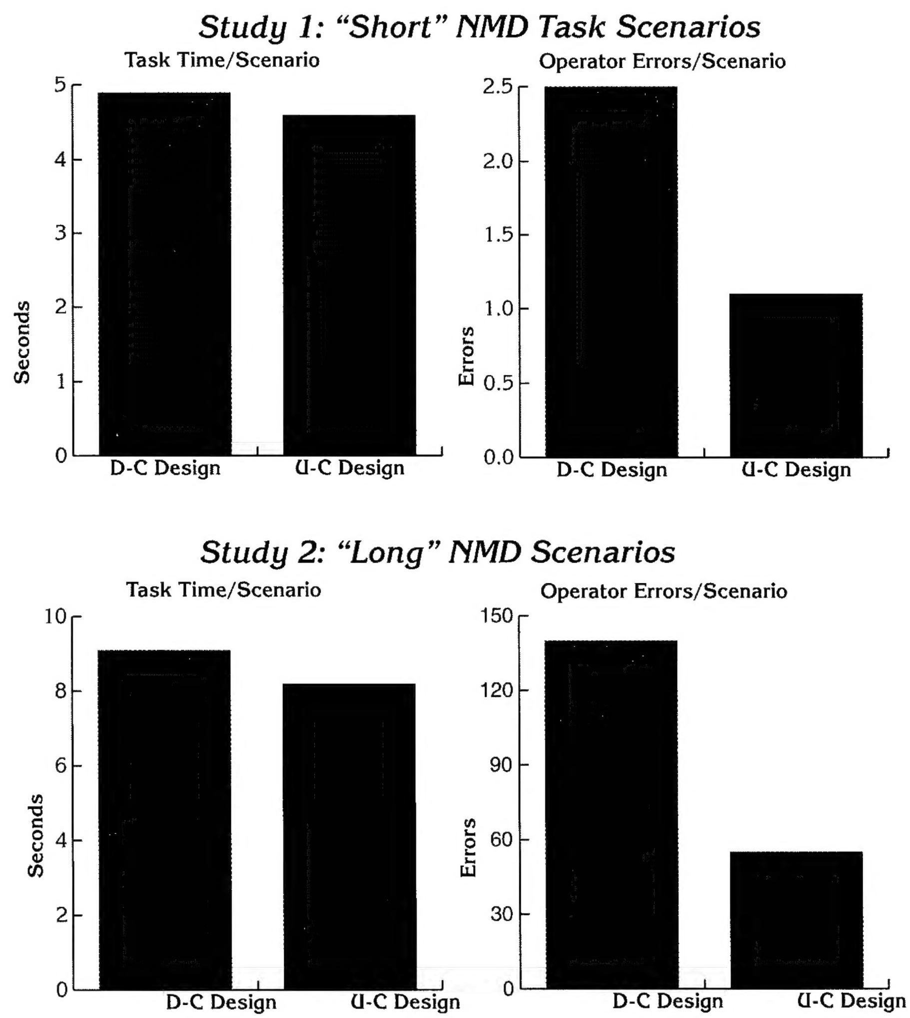
Recently, the efficacy of the user-centered process was evaluated during the development of command and control (C2) systems for the National Missile Defense (NMD) program (see Figure 1). The missile defense arena offers an ideal environment to compare user-centered and data-centered designs, because recent advances in information systems technology have increased the quantity and quality of information available to warfighters through C2 systems. Figure 2 provides a general comparison between the user-centered and the data-centered design processes.

The need for a comparison study grew out of observations made during recent testing of NMD C2 prototypes designed using a data-centered approach. In simulations using these displays, operators responded with an insatiable appetite for additional data. Their demand for more information in turn reinforced the developer's search for data-centered solutions. These observations prompted a question: Did the operators' desire for more data reflect a genuine need to process additional information to accomplish the mission, or did it indicate that the operators could not effectively use the information already available?

The data-centered designs invited confusion, it seemed, by presenting data without first associating it with specific user tasks or decision-making. In response, the operators reacted to the confusion by requesting more (i.e., better) data in future versions of the software. Based upon these observations, assessments were conducted to examine whether user-centered designs might increase operator performance when compared to data-centered designs for similar tasks.

In the usability assessments sponsored by the National Missile Defense (NMD) program in February 1998 at the Joint National Test Facility in Colorado Springs, Colorado, prototype user-centered designs were compared with existing data-centered designs. During two separate studies, trained operators were presented with scenarios simulating a missile defense mission, which required them to perform key tasks. In each study, operators were given either the familiar data-centered C2 displays or prototype displays developed specifically for the studies using a user-centered approach.

Figure 3. Results from Studies Comparing Operator Effectiveness Using Data-Centered vs. User-Centered User Interface Designs for Two NMD Tasks.



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The data-centered displays depicted all information deemed necessary for the task in a manner closely approximating the presentation style of the actual NMD C2 system. In contrast, the user-centered displays presented essentially the same raw data, but the information was reorganized and processed in ways specifically intended to support the operator's tasks and decisions. As a result of this redesign, the user-centered prototype generally presented more useful information to the operator using substantially less raw data overall than the data-centered C2 displays. The visual effect of the user-centered redesign was a simpler, cleaner display with less clutter and less navigation required.

In the first study using a short NMD task, operators' performance improved using the user-centered design. Errors decreased 56% ($p \leqq 0.001$) and performance time decreased 6.5% ($p \leqq 0.001$) (see Figure 3). A second study conducted using a similar methodology combined with a longer NMD task scenario yielded similar results. Study 2 found a 61.1% decrease in errors and a 10.6% improvement in performance time for operators using the user-centered prototype as compared to operators performing the same tasks on data-centered designs.

Underscoring the strength of these findings was the fact that operators participating in these studies reported an average of 130 hours experience using the data-centered C2 displays but less than one hour of experience using the user-centered prototype displays prior to the study. These findings point to the potential training benefits offered by user-centered designs, in addition to their demonstrated performance benefits.

Meanwhile, development continues on NMD C2 systems, using both data-centered and user-centered designs. If user-centered design is to gain greater influence in government software procurements, human factors professionals must carry the torch within the development community. Grading software acceptability by operator performance and satisfaction criteria may offer the key to encouraging a user-centered focus, but ultimately the operator community must recognize the superiority of user-centered products and specifically demand them in the requirements language provided to developers. In other words, expectations drive outcome.■

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Developing a Suppression-Sensitive Synthetic Dismounted Infantry Team

Michael Fineberg

In the last issue of *Gateway*, I described briefly how we identified parameters of suppressive fire from the literature that have been shown to affect the performance of troops in the field. In this issue I will address our "proof-of-concept" approach to quantifying the relationship between these independent variables characterizing suppressive fires and normative human responses that may manifest themselves during exposure to such a trauma. To bound the effort, we chose three independent suppression variables to represent soldier interaction with suppressive fire: intensity of bombardment in terms of rounds per minute, proximity of detonation in meters, and the bearing of the fire (i.e., in front, to the side, or in back of the troops). This example uses a 155-mm artillery for suppressive fire.

The first step in the modeling process was to hypothesize a logical, defensible relationship among these variables. We know from the literature that as explosions get nearer, happen more frequently, and last longer (up to a half-hour), the effects of suppression increase and the probability of selecting the best course of action declines. Therefore, if a suppression-sensitive synthetic dismounted infantry (SynDI) model is to emulate a soldier's response to suppressive fire, we hypothesized that the most important effect to model is the decrement in the probability of selecting the best course of action (COA) for a particular set of conditions.

Assume for this discussion that the SynDI model experiencing suppressive fire has a fixed number (N) of choices, or COAs, such as an assault or withdrawal. In the case where there is no suppressive fire, the SynDI model periodically comes to a decision point and chooses one of the N COAs. At each of these decision points, the soldier makes a rule-based choice that is always doctrinally correct.

In this model, we assumed that the effect of suppressive fire (S) has a value between 0 and 1. The index S is calculated from the combined characteristics of the suppressive fire as perceived by the soldier. With no suppressive fire, the value of S is 0, and the soldier chooses the doctrinally correct COA. With maximum suppressive fire, the value of S is 1, and the soldier chooses randomly among the COAs, without regard to which is doctrinally correct. If there are N choices, the probability of making the correct choice is $1/N$. Assuming all COAs are equally likely, this phenomenon may be represented mathematically as follows:

$$P_{cor}(S) = 1 - \left(\frac{N-1}{N}\right)S.$$

Using this equation, $P_{cor}(S) = 1$ at best case and $1/N$ at worst case.

In this model, there are three independent variables that determine the suppression index S:

- the intensity (I) of the suppressive fire in rounds per minute
- the radial distance (R), in meters, from the soldier to the impact point of the rounds
- the azimuth angle (f) of the impact point relative to the synthetic soldier's forward direction.

The suppression index S is assumed to be the weighted product of individual functions of I, R, and ϕ:

$$S = j(I)g(R)h(\phi).$$

The weighting functions j, g, and h each range from 0 to 1, allowing any one of the independent variables to reduce the effectiveness of fire suppression.

Intensity of Fire (I)

The influence of intensity of fire on the suppression index is given by the function

$$j(I) = \min[0.20\sqrt{I}, 1.0].$$

As I increases, j increases from zero at no rounds per minute to its maximum value of 1 at 25 rounds per minute.

Proximity of Fire

The effect of the proximity of fire on the suppression index is given by the function

$$g = \min\left[\frac{63}{(R + .01)}, 1.0\right].$$

The function g varies from near zero for very great distances, inversely with R until it reaches its maximum value of one as rounds get as close as 63 m. (The increment of .01 is added to R to prevent calculation difficulty if R is set to 0. It has little effect when R is greater than 63 m.)

Bearing of Fire

The bearing or direction of round impact relative to the forward direction of the unit affects the suppression index through the function

$$h(\phi) = 0.75 + 0.25\cos\left(\frac{\phi}{2}\right).$$

Here, $h = 1.0$ for round impact in front of the unit, 0.92 when a round impacts to the side of the unit, and its minimum value of 0.75 for round impact behind the unit. Note that direction alone cannot reduce the suppressive index to 0. The largest effect is a 25% reduction in the index. The coefficients in these equa-

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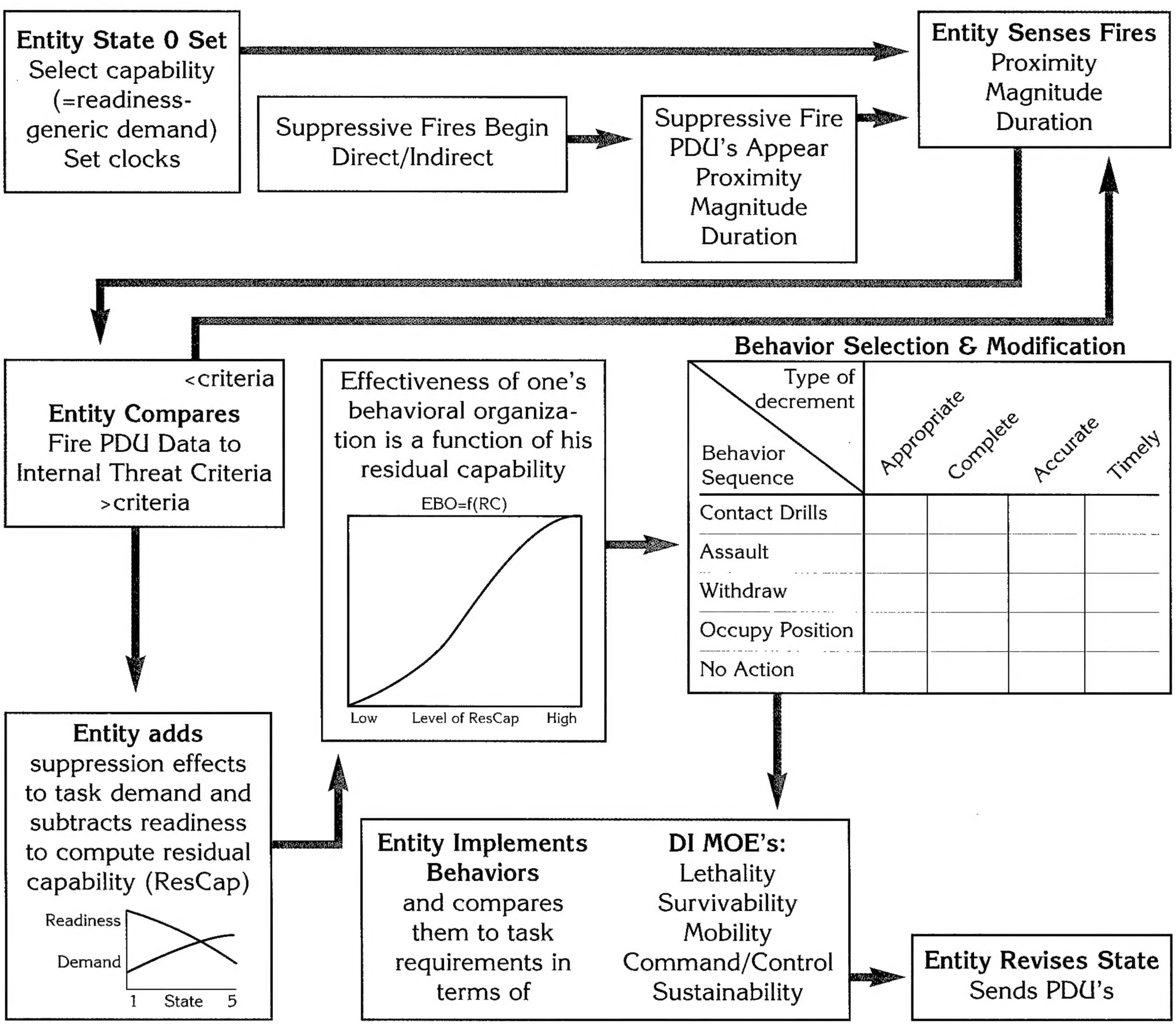
Figure 1. SynDI model response to suppressive fires



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Alexandria, VA, USA. May 10-13, 1999
42nd Biennial Meeting of the U.S. Department of Defense Human Factors Engineering Technical Advisory Group
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Pittsburgh, PA, USA. May 15-20, 1999
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San Jose, CA, USA. June 1-4, 1999
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Piney Point, MD, USA. June 8-9, 1999
4th Annual Symposium and Exhibition on Situational Awareness in the Tactical Air Environment
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Linkoping, Sweden. June 15-17, 1999
Annual International Conference on TQM and Human Factors
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1999

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September 15-October 15, 1999
Second International Cyberspace Conference on Ergonomics
Details at http://cyberg.curtin.edu.au/

Houston, TX, USA. September 28-October 2, 1999
43rd Annual Meeting of the Human Factors and Ergonomics Society
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Yellow Springs, OH, USA. October 20-22, 1999
Short Course in Anthropometric Measurement
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nov

Albuquerque, NM, USA. Nov 1-4, 1999
43rd Biennial Meeting of the US Department of Defense
Human Factors Engineering Technical Advisory Group
Contact Sheryl Cosing, 10822 Crippen Vale Court, Reston, VA 20194, USA. Phone: (703) 925-9791, Fax: (703) 925-9644, E-mail: sherylynn@aol.com, URL: http://dticam.dtic.mil/hftag/ hftag.html. Meeting is open to all government personnel and others by specific invitation.

Albuquerque, NM, USA. November 15-19, 1999
70th Shock and Vibration Symposium
Contact Sue Damanda, SAVIAC, 2231 Crystal Drive, Suite 711, Arlington, VA 22202, USA. Phone: (703) 412-7712, Fax: (703) 412-7500, E-mail: damanda_sue@bah.com

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tions will be different for weapons other than 155-mm artillery.

To understand how the suppression-sensitive SynDI team model would operate on the virtual battlefield, we constructed the operations model in Figure 1 that illustrates how a SynDI model might respond to suppressive fires given the formulas for doctrinally correct COA above. This operations model is derived from a theory of human behavior developed by Fineberg (1997) and reported in an earlier issue of *Gateway*.

Several readers noted that in the last issue two tables in the chief scientist's column were incorrectly labeled. Table 2 should have been labeled "Rounds Per Minute for Two Levels of Suppression" and Table 3 should have read "Proximity Necessary to Result in Two Levels of Suppression." Sorry for the confusion. JAL.

The first step in exercising the suppression sensitive (SynDI) model is to initialize various parameters of the simulation. These parameters were extracted from a representative mission scenario developed by subject-matter experts. The scenario description includes the mission to be accomplished, the enemy disposition, threat characteristics, the terrain, the weather conditions, and the critical mission times. The combination of parameters in the scenario establishes the initial generic "demand" on the SynDI model that corresponds to the demand in the theory of human behavior. The next step is to establish the mission start time, the beginning of suppressive fires, the duration of fires, the rate of fires, the time of cessation of fire, and the time of residual suppressive effects (dependent on the rate and volume of fire). The initial state of readiness of the SynDI model would also be set to represent fully trained and rested troops, or troops who had already experienced some degradation in their readiness before the exercise begins.

Using Monte Carlo techniques (random-number generators), the model generates the firing of artillery shells and their impact points. The suppressive effect of each shell landing is computed by the model above [based on intensity (I), distance (R), and angle (ϕ)], and averaged over the time period of the barrage to get an overall effect of the suppressive fire. The model repeats this for a number of different aim points (direct and indirect). The model then compares this result to a set of criteria that describe the threat's disposition and its cover and concealment which, in this case, are viewed as the same. In each run through the scenario, the model re-computes its residual capability to continue the mission.

The difference between readiness and demand defines residual capability (RC). If the demand is extremely high it will exceed readiness no matter how well the troops are prepared. This results in the development of "responses" in the SynDI model whose analogues in real soldiers include such symptoms as inability to make decisions, stomach distress, panic reaction, etc. These "virtual symptoms" interfere with, disrupt, or impede the selection of behaviors that are appropriate to the task at hand.

In the case of suppressive fires, behaving effectively could mean taking protective cover until the barrage is over. The extremely high demand increases the probability that the behaviors chosen by the SynDI model will *not* be appropriate to the task, may be carried out inaccurately if at all, and may take so long that they are ineffective. The outcome of this interference with the selection and implementation of combat behaviors will be to decrease mission performance in terms of lethality and survivability of the SynDI model. On the other hand, if the demand is very low, there will be no noticeable decrement in performance with regard to implementing the proper course of action as dictated by the level of suppressive fire.

A proof of concept demonstration was conducted in November 1996 using the Modular Semi-automated Forces (ModSAF) model, version 2.1. In over a dozen model runs, suppressive fires affected the behavior of the SynDI in various ways. In some runs the SynDI "dove for cover," while in others it veered away from the point of impact. In addition, not all of the SynDI in the group engaged in the same responses, nor did it continue the selected behavior for the same amount of time. To my knowledge, it is still the only working representation of human behavior that is sensitive to stresses in the virtual environment.

As always, I invite your comment and discussion regarding this article.■

Michael Fineberg, Ph.D., is the Chief Scientist for the CSERIAC Program.

References

Fineberg, et al. (1997). *Modeling the Effects of Suppression in Synthetic Dismounted Infantry.* DSWA-TR-97-79, Defense Special Weapons Agency, Alexandria, VA.

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Dear CSERIAC:

To show the diversity of support that CSERIAC provides, this column contains a sampling of some of the more interesting questions asked of CSERIAC. In response to these questions, CSERIAC conducts literature and reference searches, and, in some cases, consults with subject area experts.

These questions were compiled by Debra Urzi, Human Factors Engineer. If you would like to comment on any of these questions or issues related to them, please write to "Dear CSERIAC" at the address found on the back cover of *Gateway*.

- A laboratory director for the US Air Force requested data regarding night vision goggle (NVG) target illuminators.
- A chief scientist for the US Air Force requested information on simulator effectiveness.
- CSERIAC was contacted by an independent consultant from New York requesting spine anthropometry data.
- An Italian automobile manufacturer sought information on Asian-Indian anthropometry data.
- Information was requested by a senior scientist from a technology company in California regarding 24-hour noise limits for humans.
- An electronics engineer from the US Air Force requested data on the design of aircraft cockpit displays.
- A North Carolina ergonomist requested information on the ergonomics of handguns and holsters.
- CSERIAC was contacted by a representative of the US Navy to obtain information on vendors and points-of-contact relating to communication devices that are compatible with respirators.
- A midwest researcher contacted CSERIAC to request referral to an AF subject-matter expert on immersive virtual environments.
- A corporate president from Georgia requested information regarding the design of an aircraft clear air turbulence detection and display device.

Control Versus Dependence Striking the Balance in Function Allocation

Eric Hollnagel

Editor's note: Following is a synopsis of an invited colloquium given by Dr. Erik Hollnagel, Principal Advisor for the Organization of Economic Cooperation and Development (OECD) Halden Reactor Project, Halden, Norway on May 6, 1997. Dr. Michael Vidulich, Air Force Research Laboratory Crew System Interface Division, Wright-Patterson Air Force Base, OH, prepared this synopsis. JAL

The major theme of the presentation was that when the designer chose to allocate functions between human operators and automated systems, one way to think about the outcome was whether the operator was in control of the system or if the system was in control of the operator. A system controlling the operator constitutes a form of dependence that good design should avoid.

Some of the problems with current automation practices stem from the reasons behind using automation and the philosophies that have guided the implementation of automation. Traditionally the push to automate has resulted from either evolutionary pressures or reaction to accidents. The evolutionary pressures are the result of advancing technology making it possible to automate something that was not previously possible. Once this technology becomes available, it is nearly inevitable that some system designer will attempt to incorporate it. The reactive pressures follow any accident that occurs with the system. Following the accident, designers will often attempt to introduce any possible automation that prevents repetition of the accident. The problem with these traditional reasons for automating is that they fail to consider either the context within which the operator must perform or the interaction between the operator and the automation.

The negative effect of these traditional reasons for automation is exacerbated by the typical "philosophies" that usually guide the application of automation. Most pernicious is the "Left-Over" principle. This is the philosophy that the designer will automate anything that can be automated and leave the remainder for the human operator. This approach does not take into account the value added by the human operator nor does it really consider the implications of the interaction of the operator and the system.

A somewhat better philosophy for guiding the allocation of automation is the "Compensatory" principle. This principle was inspired by the initial work of Paul Fitts and encourages the designer to identify the strength and weaknesses of humans and machines, and assign their functions based on these abilities and limitations. While this can be seen as a more insightful approach than using the Left-Over principle, it still suffers from an assumption that human operators possess fairly static information-processing capabilities and that the optimal interaction between the operator and the machine can be successfully described a priori.

Hollnagel advocated a different philosophical approach to allocating functions within a system to either the human operator or automation. This approach is called "Complementary" allocation. Central to this approach is viewing the combination of the human operator and the automated machine as a joint cognitive system in which the cyclical information processing of the human operator is in dynamic equilibrium with that of the automated system.

Both the human and some automated machines are considered to be cognitive systems because they both can exhibit four features during task performance: (1) they are adaptable, (2) they appear to use a model of the world, (3) they appear to use a model of the self, and (4) they are goal-oriented. Hollnagel provided a more modern and succinct definition: "A cognitive system can modify its pattern of behavior on the basis of past experience so as to achieve certain anti-entropic ends." According to this definition, most organisms, many machines, and even some organizations can be considered to be cognitive systems.

Hollnagel suggested that to understand the interaction of the human operator and the automated system as a joint cognitive system required looking beyond the standard information-processing model favored by many researchers. Hollnagel believes that this standard model was too limiting in that it failed to appreciate the role of context beyond being part of the system input and failed to capture the dynamic cyclical nature of cognitive systems. Within a cognitive system, a perceptual cycle is seen as continuously cycling from observation, to information, to understanding, to guide further information seeking observations, and so on. The pure perceptual cycle would also be a part of an action cycle in which the cognitive system's action influenced future observations and understanding.

Control of the system can only be maintained if the information resulting from current observations matches the expectations generated as part of the previous cycle's understanding. It is here that a poorly implemented automated system can cause the most obvious troubles. If the automated system acts in such a way that the human operator's expectations are violated, this causes a loss of control on the part of the human operator. If this process continues, the situation can become unstable with the operator increasingly driven by the system. Such a loss of control is said to be caused by "event escalation."

"A cognitive system can modify its pattern of behavior on the basis of past experience so as to achieve certain anti-entropic ends."

At OECD Halden Reactor Project, Hollnagel and his colleagues have developed a model to study the interaction of contextual variables and control in joint cognitive systems. The model is called the Contextual Control Model, or COCOM. COCOM describes action sequences as contextual in nature rather than as pre-defined. In other words, the actions chosen by cognitive systems are controlled by the current context and can be both reactive or proactive. Hollnagel describes COCOM as a cybernetic model rather than a psychological model.

One of the main features of COCOM is the different control modes in which the cognitive system can operate, depending upon circumstances. The four possible control modes are scrambled, opportunistic, tactical, and strategic. COCOM suggests that there are two important aspects of performance determined by the current control mode. Control mode affects the choice of the next action and the evaluation of the outcome resulting from any action.

Dr. Eric Hollnagel, OECD Halden Reactor Project

In the scrambled control mode, the next action is determined by an unreflective reaction to the dominant characteristics of the situation and the evaluation is pretty much limited to "Am I better off than before?" In the opportunistic control mode the selection of the next item will generally come from a list of good things to do, but the selection will be unconstrained by the current context. In evaluating the outcome of an opportunistic action, COCOM will be very concerned with whether the current observations are feedback from the previous actions or constitute a new event. Tactical control mode is very similar to the opportunistic except that the action selection will incorporate some appreciation of the current context and the evaluation will be more sensitive to delayed feedback. The strategic control mode will add consideration of side effects to other goals in the selection and evaluation of any actions.

Obviously, the most effective performance will be achieved when the human operator (and the entire joint cognitive system) is operating in the higher control modes. COCOM predicts that shifting between control modes will be strongly influenced by the subjectively available time and the familiarity of the situation. If subjectively available time and familiarity are both low, the human operator will be forced towards the scrambled control mode. As either subjectively available time or familiarity is expanded, the human operator will be more likely to move to a higher control mode.

In conclusion, Hollnagel stated that automation design (and system design) requires adequate models of joint system functions. The research at the OECD Halden Reactor Project and the COCOM model can be viewed as an attempt to start the specification of such models. ■

Rotorcraft Human Factors Research Facilities at the NASA Ames Research Center

Jay Shively

Figure 1: UH-60A RASCAL

In April of 1997 the Army/NASA Rotorcraft Division was formed at the NASA Ames Research Center. The goal was to create a synergy of Army Aeroflightdynamics Directorate and NASA Ames rotorcraft resources. The mission of this 124-member organization is to lead the nation in aeromechanics, flight control, and cockpit-integration technology development. Its products have application to military and civil helicopters, tilt-rotor aircraft, and other advanced rotary-wing aircraft.

The Flight Control and Cockpit Integration Branch is responsible for the development and insertion of advanced controls, guidance, and display technology for rotorcraft and powered-lift aircraft, and for the integration of these technologies to achieve safer and more effective pilot-vehicle performance. Within this branch, the Human Systems Integration group consists of about a dozen researchers whose emphasis is rotorcraft human factors. The projects in this group include a major effort on human-cognitive modeling, MIDAS, as well as efforts to increase rotorcraft safety. This latter effort is the situation awareness and information display (SA & ID) element of the Safe All-weather Flight Operations for Rotorcraft (SAFOR) program. The SA & ID element focuses on such topics as training, obstacle detection and depiction, civil use of night-vision systems, and simulator fidelity requirements for auto-rotation, among other topics. The facilities available for this group are varied and support this wide range of research efforts. These are described below.

Low-/Mid-Level Fidelity Simulators

The Rotorcraft Part-Task Laboratory (RPTL) is a workstation-based simulator equipped with a dynamic out-the-window view and real-time instrument display. The simulation is controlled by a very flexible scenario development system. This system was developed to study such topics as situation awareness, obstacle avoidance displays, and moving-map display formats. The pilots control this simulation through low-fidelity helicopter controls.

The Pilot/Rotorcraft Intelligent Symbology Management Simulator (PRISMS) has been designed to aid in developing and evaluating inno-

vative and intelligent information presentation systems for helmet-mounted displays (HMD) in military helicopters. PRISMS is a sophisticated but relatively inexpensive simulator taking advantage of the most recent advances in technology. PRISMS offers HMD symbology in screen-fixed, aircraft-fixed, and earth-fixed frames of reference, overlaying a gaming area of realistic terrain adapted from the Southwest United States. An immersive approach with an opaque visor has been used, providing an effective virtual reality experience. Cyclic, collective, and pedal controls may be used in flight throughout the terrain, facilitating demonstrations, knowledge acquisition sessions, and controlled experiments.

Modeling Tool

The Man-machine Integration Design and Analysis System (MIDAS) combines graphic equipment prototyping, dynamic simulation, and human performance modeling aimed at reducing design cycle time, supporting quantitative predictions of human-system effectiveness, and improving the design of crew stations and their associated operating procedures. MIDAS comprises models of both major components of human-systems integration, the human operator, and the system, or environment.

High-Fidelity Simulator

The Vertical Motion Simulator (VMS) is a world-class research and development facility that offers unparalleled capabilities for conducting experiments involving aerospace disciplines. The six-degree-of-freedom VMS, with its 60-foot vertical and 40-foot lateral motion capability has the world's largest amount of displacement in a motion-based simulator. The large-amplitude motion system of the VMS was designed to aid in the study of helicopter and vertical/ short take-off landing (V/STOL) issues specifically relating to research in controls, guidance, displays, automation, and handling qualities of existing or proposed aircraft. Recent simulation projects developed and conducted at the VMS include High-Speed Research (High-Speed Civil Transport), Advanced Subsonic Transport/Short-Haul Civil Transport (Civil TiltRotor), Common Affordable Lightweight Fighter (Advanced Short Take-Off Vertical Landing), and Space Operations (Space Shuttle Orbiter).

Research Aircraft

RASCAL is a UH-60A Black Hawk helicopter which is being configured as a highly capable and flexible crew station research facility (See Figure 1). It is being equipped with programmable flight controls and active backdriven sidearm controllers which together are capable of allowing the pilot to maneuver at the aircraft limits embodying automated and intelligent envelope limiting and cueing. Programmable cockpit displays, targeted at improving safety and mission effectiveness, are also planned for evaluation in the aircraft.

The Flying Laboratory for Integrated Test and Evaluation (FLITE) research aircraft is used for human performance and man-machine integration tests of night-vision displays, night-vision imaging sensors, computer-voice input/output systems, active noise reduction systems, integrated audio caution/warning systems, and advanced radio communication systems. In addition, the aircraft was used to gather vibration data for an intelligent gearbox health and usage monitoring system.

To accomplish the research goals, the FLITE aircraft has a number of modifications. This AH-15 aircraft (See Figure 2) has the same Pilot Night-Vision Sensor (PNVS) System as the Apache AH-64 aircraft. This system presents thermal imagery to the pilot on a helmet-mounted display from the infrared, head-slaved, imaging sensor on the nose of the aircraft.

Conclusion

This wide range of research options provides the Human Systems Integration Group with the great advantage of performing low-cost simulation and modeling for concept development when appropriate, and then moving the mature technologies to ever-increasing levels of realism culminating in the very important step of flight test and validation. ■

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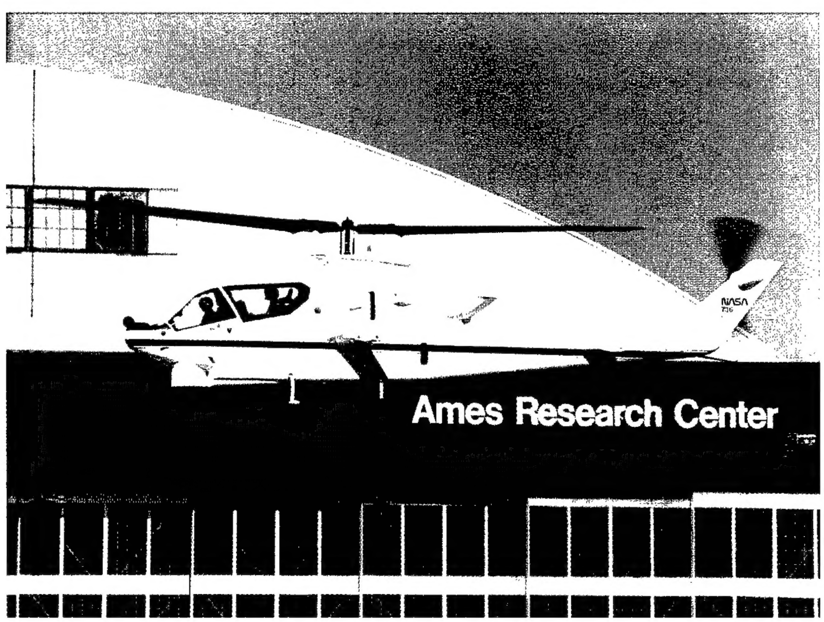
Figure 2: AH-15 Flite Cobra



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